Experience with Modular Design in Energy Storage Systems

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Modular Energy Storage System
Increase of Flexibility, Scalability and Reliability

Conventional Approach

- Smart Network Control
- System Control
- Inverter Control
- Data Logging
- Battery Management

Modular Approach

- Grid
- Switchgear
- Transformer
- Filter
- AC/DC Inverter
- DC Breaker

1- Micro Inverters
2- Single Battery Rack

1 2
Two proposed modular designs to attend customer’s need

1st Design
- Minimum exposure to DC
- Paralleling on AC Side
- No Balancing of Batteries
- Easy Extension
- No “Rotten Apple” Effect
- High Availability

2nd Design
- Integration to any Battery supplier

A
B
C

Paralleling on AC Side
No Balancing of Batteries
Easy Extension
No “Rotten Apple” Effect
High Availability
“Unit Commitment” to generate desired wave form at Point of Interconnection (POI)

Modular Design

Individual 2-Level Inverter

Conventional Design

Multilevel Inverter

Power Control Unit manipulates each wave form generated by all inverters
Modular Design offers higher efficiency during charges and discharges below installed power.

During low power operation, a modular system can work on a higher efficiency level than a similar size conventional system.

By shutting off unneeded inverters, the modular system can reduce standby loads and auxiliary power losses (HVAC, etc).
Most applications require quick variation of the E-Storage system output

Report from a customer…
In certain circumstances, the power generation fluctuates from 100% to 40% (Nominal rate) within 30 s

Utility Code…
A 10 % per minute rate (based on AC contracted capacity) limitation shall be enforced
Interconnection on AC side prolong system longevity and promote system enhancement

1 – Possible uneven SOC across batteries
2 – Simple increment of power and capacity
3 – Easy implementation of redundancy
4 – Adaptation of different Suppliers /Vdc
5 – Possible mix of Technologies
6 – Neutralization of uneven aging / internal resistance
Modular design can reduce footprint and increase system safety and availability

Coventional Approach: One Inverter, One DC Breaker, Parallelism on the DC side

Modular Concept: Multiple Inverters & Parallelism on AC side
Modular design: how it operates (1/3)

Maximum Contractual Power

GRID

POI

Utility

Battery

LOAD

TIME

T = t

$/kWh

$\$/kWh

STORAGE

Load
Modular design: how it operates (2/3)

1. Measurement is taken, history data is kept for projection.
2. Past data is used for algorithm adaptation.
3. Once adapted, algorithm projects next measurement.
4. Charge/Discharge is programmed based on the difference between the maximum and \( P(t+1) \).

\[
P_{\text{Discharge}}(t+1) = P(t+1) - P_{\text{Max}} = 10.5 - 10 = 0.5 \text{MW}
\]

\[
P(t+2) = 10.5 \text{MW}
\]

\[
P(t+1) = \alpha + \beta \text{ to } - ...
\]

\[
P(t+1) = \alpha + \beta \text{ to } - ...
\]

Maximum Contractual Power
Load Profile

IEEE Power & Energy Society
Modular design: how it operates (3/3)

P Discharge = 500kW

```
Inv 1 = 0%
Inv 2 = 24%
Inv 3 = 26%
Inv 4 = 23%
Inv 5 = 27%
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**High Priority**

1 – Total Charge/Discharged is determined
3 – Setpoints for every inverter is calculated

**Low Priority**

3 – Supervision of status of Inverters and Batteries
4 – Calculation of contribution of every power string
Notes on Modular Design Availability: Sample Project

Availability = \[ 1 - \left( \sum \text{outage duration (hrs) x lost capacity (MW)} \right) \] \times 100%

(8760 hrs x 6 MW)

Requirement: 97%

Project Consideration: 6.0 MW
65 Power String + 3 Spares

Influence of Power Equipment failure

Influence of Communication Equipment failure
Notes on Modular Design Availability: Sample Project

Availability 99.55%

To reach 97% the calculated downtime would have to grow by a factor of 6.7 (1,576,800 / 234,840)
Lessons Learned from our Experience with ENEL Project
1MVA / 500kWh

ENEL/Italy - Commissioning in February 2012

1 – Single HVAC Condenser
2 – Metal Duct mounted on container ceiling
3 – Water Infiltration due to metal contraction (duct)
4 – Damage of one inverter module. Remaining units into normal operation
Distributed Energy Storage: A “modular approach” to address all System needs

- **Bulky Storage**
  - Resource Adequacy
  - Frequency Regulation
  - Time Shifting
  - Renewable Firming
- **Ancillary Services**
  - Spinning Reserve
  - Ramping Control
  - Black Start
  - Reactive Power
- **Upgrade Deferral**
  - Congestion Relief
  - Voltage Support
- **Renewable Smoothing**
- **Peak Load Management**
  - Power Quality
  - Backup Power
  - Diesel Off-set

- **Photovoltaics** & concentrated solar power
- **Wind power**
- **Conventional Generation**
- **Transmission**
- **Distribution**
- **Residential**
- **Large commercial**
- **Industrial**